

TOTAL QUALITY MANAGEMENT: ANALYSIS, EVALUATION &
IMPLEMENTATION WITHIN ACRV PROJECT TEAMS

Final Report

NASA/ASEE Summer Faculty Fellowship Program--1991

Johnson Space Center

Prepared by: Laura B. Raiman, Ph.D.
Academic Rank: Assistant Professor
University & Department: Pennsylvania State University
Department of Industrial &
Systems Engineering
University Park, PA 16802

NASA/JSC

Directorate: New Initiatives Office
Division: ACRV Project Office
Branch: n/a
JSC Colleague: Brian K. Kelly
Date Submitted: August 9, 1991
Contract Number: NGT-44-001-800

ABSTRACT

Total Quality Management (TQM) is a cooperative form of doing business that relies on the talents of everyone in an organization to continually improve quality and productivity, using teams and an assortment of statistical and measurement tools. The Assured Crew Return Vehicle (ACRV) Project Office was identified as an excellent project in which to demonstrate the applications and benefits of TQM processes. As the ACRV program moves through its various stages of development, it is vital that effectiveness and efficiency be maintained in order to provide the Space Station Freedom crew an affordable, on-time assured return to Earth. A critical factor for the success of the ACRV is attaining the maximum benefit from the resources applied to the Program.

Through a series of four tutorials on various quality improvement techniques, and numerous one-on-one sessions during the SSF's 10-week term in the Project office, results were obtained which are aiding the ACRV office in implementing a disciplined, ongoing process for generating fundamental decisions and actions that shape and guide the organization. Significant advances were made in improving the processes for two particular groups - the correspondence distribution team and the W.A.T.E.R. Test team. Numerous people from across JSC were a part of the various team activities including Engineering, Man Systems, and Safety. The work also included significant interaction with the support contractor to the ACRV Project. The results of the improvement activities can be used as models for other organizations desiring to operate under a system of continuous improvement. In particular, they have advanced the ACRV Project Teams further down the path of continuous improvement, in support of a working philosophy of Total Quality Management.

INTRODUCTION

Total Quality Management (TQM) is a cooperative form of doing business that relies on the talents of everyone in an organization to continually improve quality and productivity, using teams and an assortment of statistical and measurement tools. JSC management has made a commitment to understanding TQM techniques, and to implementation within JSC organizations. The ACRV (Assured Crew Return Vehicle) Project Office was identified as an excellent project in which to demonstrate the applications and benefits of TQM processes. As the ACRV program moves through its various stages of development, it is vital that effectiveness and efficiency be maintained in order to provide the Space Station Freedom (SSF) crew an affordable, on-time assured return to Earth. The challenge is magnified by an increasing pressure to adhere to schedule, cost and technical objectives. A critical factor for the success of the ACRV is attaining the maximum benefit from the resources applied to the Program.

This paper documents the work performed over a 10 week period which involved examining and assessing the processes being utilized by the ACRV Project teams from a total quality perspective. A major portion of this work involved determining specifically where certain statistical tools would be appropriate, and demonstrating their application. Major areas of interest included ACRV testing techniques, probability of mission success (POMS), operational availability (A_o), and strategic planning. The results from this study are aiding the ACRV office in implementing a disciplined, ongoing process for producing fundamental decisions and actions that shape and guide the organization. The resulting activities of the ACRV Project teams will serve as models for other organizations which are attempting to use TQM effectively to anticipate and respond to changing environments.

METHODS IMPLEMENTED FOR IMPROVEMENT ACTIVITIES

The activities conducted over the summer were supported by a series of four tutorials presented by the Summer Faculty Fellow (SSF). After discussions with ACRV Project Office managers and team members concerning Project Office activities and methods, the SSF decided that it was necessary to provide training in some of the quality analysis techniques. Once training was completed in each area, the existing knowledge of the team members could be integrated with the new analysis techniques in order to achieve a direct application of the numerous quality improvement techniques. This immediate application not only

helps implant a solid understanding of each technique, but also generates enthusiasm since people have the opportunity to immediately apply new techniques. The four tutorials presented were as follows: TQM: Philosophy & Tools; Design of Experiments; Quality Function Deployment; and Benchmarking. (Copies of the materials presented in these tutorials may be obtained by contacting the SSF or the ACRV Project Office). The contents of each of the four topics are described below.

TQM: Philosophy & Tools

Process improvement is aided by viewing an organization as a network of linkages of processes run by internal producers and customers of output. The ultimate output of this network is the product or service provided to an external customer. Quality and productivity are improved as producers work in teams with their suppliers (internal and external) to improve internal customer satisfaction and hence external customer satisfaction. The focus of quality improvement therefore, must be on identifying and improving the key processes in each function of each department in an organization. Incremental process improvements must be made on an ongoing basis. The strategy for achieving these process improvements involves three major activities: 1) selecting the process, 2) documenting the current knowledge of the process, and 3) using an improvement cycle to increase the knowledge of the process. A basic model (developed by Associates in Process Improvement) for process improvement is shown in Figure 1.

The last activity in the strategy is the iterative use of the improvement cycle. The use of this cycle is meant to increase users' knowledge of a process. This cycle is also referred to as the Shewhart Cycle, Deming Cycle, and plan-do-check-act (PDCA) Cycle. In order to step through this cycle for any particular process, there are a number of quality improvement tools that may be used. The tutorial covered the use of seven of these tools: flowcharts, cause and effect diagrams, pareto charts, check sheets, histograms, control charts and scatter diagrams. These tools may be used for collection of data and/or analysis of data and information.

The final portion of this tutorial covered the concept of variation. It is vital that all team members understand some of the basic statistical concepts needed to interpret variation. They must be able to determine whether the patterns of variation that are observed are indicative of a trend or of random variation that is similar to what has been observed in the past. This distinction between

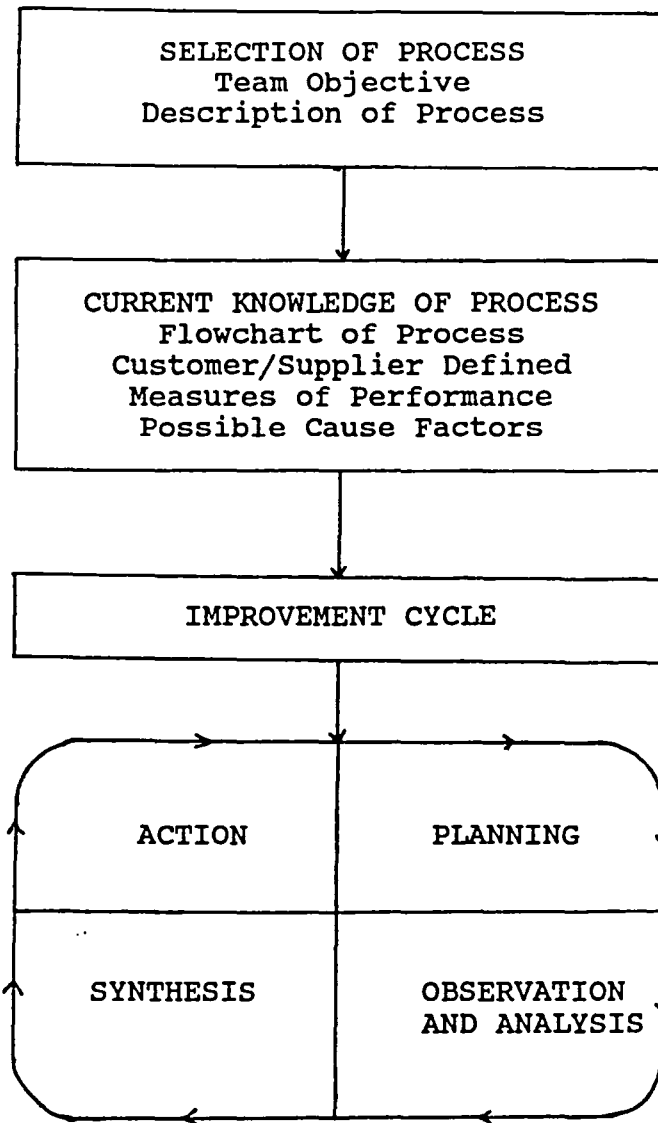


Figure 1.- Strategy for Process Improvement

patterns of variation is necessary to minimize the losses resulting from the misinterpretation of the patterns. These losses can be minimized by understanding that variation can be caused by either common or special causes, by knowing how to determine whether a system is stable or not, and by basing action on this analysis.

Design of Experiments

This tutorial covered the basics of effective experimentation. Without knowledge of statistical experimental procedure, experiments are often performed in such a way that some (or perhaps all) important questions cannot be answered. Because of the possibility of performing an ill-advised set of experiments, questions of design must be considered at the start of an experimental program. Classical approaches to experimental design, including full factorial designs and fractional factorial designs, allow for consideration of both statistical accuracy and cost. Statistical accuracy involves the proper selection of the response to be measured, determination of the number of factors that influence the response, the selection of the subset of these factors to be studied in the experiment being planned, the number of times the basic experiment should be repeated (replicated), and the form of the analysis to be conducted. To minimize the cost of an experimental investigation, usually it is preferable to choose the simplest experimental design possible and to utilize the smallest sample size consistent with satisfactory results. Fortunately, most simple experimental designs are both statistically efficient and economical.

Using the classical designs as a foundation, the basics of Taguchi Methods for Experimentation were also covered. The ideas of system design, parameter design and tolerance design were all included in this discussion. The idea of the Taguchi Loss Function was also presented, allowing for a discussion of impact of quality improvements on cost.

Quality Function Deployment

This tutorial covered the basics of QFD. This included a general exposure to the basic QFD methodology, including the "House of Quality". The House of Quality provides for complete analysis of the basic relationship matrix which relates customer needs to specific design concepts. This analysis includes a competitive evaluation, and interaction matrix relating the design concepts to one another, and the development of measures for each of the design concepts. QFD helps to integrate all of the corporate functions in being responsive to customer requirements so that product planning, product design, process planning and production planning provide a coherent response to the customer needs that achieves value and satisfaction for the customer. QFD plays a major role in achieving products that have reduced cost, better quality, features that satisfy customer's needs, and are developed in a significantly shorter

development time. As a result, the products are intrinsically much more appealing to potential customers.

Discussion of QFD concepts during the tutorial were extensive under the area of requirements. Possible applications were identified which included: relating the SPRD requirements to the three mission segments; relating the SPRD requirements to the detailed contractor requirements; defining customer requirements for computer needs in the next phases of the Project, and subsequently defining requirements for the systems which will be used to fulfill these requirements.

Benchmarking

This tutorial covered the general concepts included in Benchmarking. In simple terms, benchmarking is the continuous process of measuring products, services and practices against the toughest competitors, or those companies recognized as industry leaders. Benchmarking techniques allows the user to analyze what, why, and how leading companies have done, to earn their leadership position. Benchmarking activities must look into the future, not just the present. In order to achieve world class performance tomorrow, a company must not only eliminate the current Benchmark gap, but also must improve performance such that they surpass the current best practices in the future by setting a new standard.

The 10-step process Xerox developed to accomplish Benchmarking was presented, and an example of the techniques used by Motorola to achieve and maintain their standing as a world class company. While discussing these issues, a good period of time was spent brainstorming on who the customers are for ACRV, what companies should be considered when benchmarking processes in JSC, and how to ensure that a benchmark gap is not just filled in the present, but that world class levels are surpassed in the future.

IMPLEMENTATION OF QUALITY IMPROVEMENT TECHNIQUES

Two major team improvement activities, and implementations of quality improvement techniques occurred over the 10-week period. The first involved one team's trip through the process improvement cycle, and the second involved the improvement of test matrix design for a major testing effort. Descriptions of both of these improvement efforts are given below.

Correspondence Distribution Team (CDT)

This effort involved a team of 5 people - two NASA/ACRV personnel, and three support contractor (Eagle Engineering) personnel. The first effort of the CDT was to describe the process to be examined. The process included all correspondence distribution once it was received at the front door of the ACRV office. This included regular mail, NASA mail, faxes, electronic mail and drop-offs. The problem was that too much unnecessary paper was crossing the desk of the project manager and his secretary. As a result, important information might get lost in the mass of paper, specific correspondence could get misplaced and as a result require hours to track it at a later date.

The first step in the improvement process, after getting the team together, was to hold a brainstorming session to flowchart the existing process. In a two-and-a-half hour session, the team brainstormed all of the steps in the correspondence distribution process, they then reorganized all of the steps into flowchart form. The current flowchart was then typed up and distributed to team members. The team took one week to evaluate the flowchart, make the necessary changes, and think of ways to improve the process. One week later, members of the team got back together to brainstorm improvement ideas. A significant number of ideas were presented to help eliminate the amount of paper going across the manager's desk. After all of the improvement ideas were documented and discussed, a new flowchart was generated which incorporated the process revisions.

The final step in the improvement process for the CDT will be to implement the improvement ideas. The team got together one last time to review the improved distribution process, and make any last changes. The improved process was then presented to the manager. In addition to the numerous improvements made to the correspondence distribution process, there were also a number of other valuable aspects to the team activities. Team members gained ownership of their process, and as a result everyone understood the entire process to a much greater extent than going into the team activities. This also meant that all team members had strong buy-in to all suggested improvements.

A valuable customer/supplier relationship was strengthened since team members were not all direct NASA ACRV Project Office employees. The result of this was elimination of some barriers that previously existed between the contractor and the Project Office. Three team members

represented the support contractor to the Project Office, and therefore filled a "supplier seat" on the CDT. Members also realized the value of working as a team - recognizing that the sum of everyone's ideas is greater than what could be accomplished individually. The final benefit was the excitement generated as a result of this team's activities. Enough interest was generated that the support contractor requested the SSF to make a presentation to their top management on TQM and related tools. This step cannot help but strengthen the working relationship between the support contractor and the Project Office.

Wave Analysis & Test of Extraction Requirements (WATER) Test Plan

The second major team effort accomplished during the 10-week period was the effective design of the WATER test plan, which focuses on the post-landing phase of the ACRV mission. While the decision to bring the ACRV down to land-landing site or a water-landing site has not been made, the WATER evaluation focuses on the specific post-landing dynamics of a water-landing vehicle. The development of a full scale, generic ACRV mockup is the centerpiece of the crew egress evaluation. A substantial amount of research resulted in the capability of the mockup to simulate the water dynamics of both the Apollo and a NASA study vehicle concept, SCRAM. An entire week of unmanned testing is planned, which is devoted to the development of an engineering motion analysis database. An additional set of testing evaluations are planned to focus on the manned aspects of ACRV water recovery.

The purpose of the second tutorial on Experimental Design was to expose the WATER team members to the concepts behind effective and efficient experimentation methods. The engineering (unmanned) portion of the test deals with a large number of input variables including: horizontal C.G., vertical C.G., weight, sea state, and vehicle configuration. The response variables include static draft, flotation attitude, and pitch amplitude after disturbance. Dynamic response measures include pitch amplitude, heave amplitude, surge amplitude, yaw rate, and wave run-up magnitude. The Medical/Man Systems (manned) portion of the test deals with input variables including vehicle configuration, wave state, hatch location, and crew composition (mixture of deconditioned and ill/injured crewmembers). Each of the test levels for all the input variables had to be determined, and an effective testing scheme for combining these levels into an effective test scheme also had to be examined.

During the course of the tutorial, and individual one-on-one sessions, the members of the WATER Team were exposed to different test designs. The differences between one-at-a-time testing and orthogonal, balanced designs were thoroughly examined. Significant time was also spent discussing how to integrate the engineering and medical/man systems test objectives for the week of combined testing, in order to obtain useful data that can be used effectively to make useful characterizations.

The WATER test plan is still in the planning phase. Actual experimentation is expected to take place in late '91 or early '92. Followup work between the SSF and the ACRV Project Office will continue to examine both the design and issues involved in the WATER Test. Some preliminary test design analysis may also be examined using the 1/20th scale wave tank and ACRV models prior to the actual WATER Tests.

Miscellaneous Engineering Probability Analysis Issues

An additional assortment of engineering/reliability issues were examined during the summer. The first involved generating a landing error probability distribution, given engineering simulated footprints. Initial engineering studies were performed to estimate the targeting accuracy to a landing point of a range of ACRV configurations due to navigation, entry guidance, and parachute drift dispersions. The configurations varied in types of navigation aids employed, vehicle lift-to-drag (L/D) ratios, and parachute characteristics. From this study, an overall summary of landing footprints was provided to the SSF. This information was then used to generate a two-dimensional probability distribution which characterized the probability of landing over a given region.

Using information obtained on obstacle coverage at two specified landing sites, a probability distribution for the obstacles was also generated. When these two probability footprints were used in conjunction, it resulted in the capability of estimating the probability of the ACRV hitting an obstacle upon landing. This measure is an important factor in the overall probability of mission success.

The general ideas used for in conjunction with the above problem were also used to analyze some slightly different situations. The first one involved using historical landing data from the Apollo landings to generate confidence intervals on targeting error. The second application involved the development of a technique to evaluate the probability of surviving debris from reentry

hitting a person upon landing. The generation of the probability distributions for this method were similar to those used for landing footprint distributions. The final problem investigated was evaluating the effects of wind profiles specifically on landing error footprints. The purpose of this investigation was to determine if retargeting the ACRV based on wind profile information would cause a significant reduction in the size of the landing error footprint. This final problem is still under investigation.

CONCLUSIONS

There are a number of notable results which occurred as a result of all of the above improvement activities. In general, the members of the ACRV Project Office teams have gained a better understanding of TQM - not just as a philosophy, but also as knowledge of the tools available to support the philosophy. This has more people thinking about the available tools, and possible applications in the work and processes of the Project Office. The tutorials and the supplementary statistical work provided engineers supporting the ACRV, and Project Office members with a strengthened statistical awareness, and understanding of the use of probability distributions.

Many members of the Project Office expressed a strong interest in finding more applications, and continuing the quality improvement activities so that knowledge of the tools is not lost. For two of the Project Office Teams - Correspondence Distribution and WATER Test - there is greater team ownership, and significant improvements have been made in the processes evaluated by each of the teams.

Another added benefit coming from the tutorials and improvement activities is an increased interest on the part of the support contractor to the ACRV Project Office, and various NASA support organizations. The support contractor, Eagle Engineering, received a tutorial on TQM philosophy and tools, and are looking at how to implement TQM in their own processes. This activity will directly benefit the ACRV Project Office, since they are a customer of Eagle. With regard to the NASA support organizations, the summer activities included people from many Directorates including Engineering, S,R & QA, Man Systems, and Medical personnel. The involvement of all of these ACRV support people improves internal customer/supplier relationships, helps provide some focus on internal processes as well as external, and provides many additional people with direct experience working with TQM tools, and operating under the corresponding philosophy.

Improving product or service quality is achieved through improvements in the processes that produce the product or service. Every activity and every job is part of a process - and can be improved. Improvement comes through people and learning. The strategy for process improvement used by teams in the ACRV Project Office, especially over the course of the summer, helps provide a roadmap for further improvement. The roadmap includes the development of team members who possess the ability to determine a common objective, define the relevant process, define the current knowledge, and build on that knowledge to make a change in the process using the improvement cycle. If the enthusiasm, and team activities, initiated in the projects described in this paper are used as a roadmap into the future, the ACRV Office will realize significant improvements in processes, and will leave a well-defined trail for others to follow along the road of continuous improvement.